THE TECHNOLOGY GAP: ANALYSIS AND APPRAISAL

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In this paper I will argue five points. First, the technological gap is a meaningful concept, and the phenomenon probably is real. Second, it is nothing new; something like a technological gap between the United States and Europe has existed for upwards of one hundred years. Third, what is new about the situation and what lies behind the present strongly articulated concern expressed by Europeans has less to do with general economic well-being than with issues of national autonomy, prestige, and military power. Fourth, the reasons for the long-standing gap are complex and poorly understood but, aside from military and space technology, they probably have far less to do either with U.S. Government R&D policy, or with the size of the U.S. corporate giants, than many people seem to believe. Fifth, well meant American arguments that economic growth will not be furthered by expensive defense and space R&D programs or the development of giant corporations in Europe will not be persuasive, given the real issues involved.

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I. THE MEANING OF A TECHNOLOGICAL GAP

The concept of a technological gap is not an easy one. By a technological gap I think most people have in mind phenomena that transcend the consequences of differences across countries in factor endowments, either innate, or as developed through past investment. The operational part of the discussion of the technology gap appears to focus on better flow of knowledge of product, process, or of organization to more effectively exploit knowledge. While investment of various specific kinds -- R&D and high level technical education -- are involved in the discussion, closing the technological gap is not generally assumed to require massive transfer or application of resources.

Thus, differences in output per worker or per man hour across countries is not direct evidence that a technological gap exists between the high and lower productivity countries. The productivity differences could be the result of different amounts of resources invested, over the years, in machinery and equipment, education, training, and other intangibles, per worker. To the extent that differing levels of accumulated investment is the full explanation, to say that the difference is caused by a technological gap is both unhelpful and misleading. If less equipment is used because of lower rates of capital accumulation, if workers and managers are not as skillful because less time and resources have been involved in their training and education, the remedy is more investment. If this is all there is to it, more productive and more advanced technology

will come naturally with the investment. The technology, skill, and organization gap is a concomitant of the investment gap, rather than a separate entity to be dealt with by special actions and policies.

Until just recently most of the main line of the economics profession tended to view international productivity differences in just this way. In the formalized version of the Hecksher-Olin trade theory implicit in modern neo-classical economics, differences in output per worker (and comparative advantage) between countries are explained by differences in capital (and natural resources) endowments per worker. There is no real room in the analysis for a meaningful concept of a technological gap.

Over the last decade or so there has been growing awareness that there must be more to it than this. During the 1950s modern neo-classical economics experienced two sharp intellectual shocks. One was the discovery that the growth theory implicit in the model was grossly inadequate. Increases in capital per worker (even when education and other forms of investment were counted in) seemed incapable of explaining fully the productivity growth experienced in growing countries and obviously the model could not come to grips with the phenomenon even more impressive than productivity growth -- the tremendous enrichment and improvement in the kinds of final products produced.* The second was the failure of the Hecksher-Olin theory, in its first real empirical test, to explain U.S. trade

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*For a review of the literature see Richard R. Nelson, Merton J. Peck, and Edward D. Kalachek, Technology, Economic Growth, and Public Policy, The Brookings Institution, Washington, D. C., 1967.

patterns. It turned out that the United States did not export capital intensive products (at least not defining capital narrowly).* Related, but less well noticed in the profession, the early tests of the ability of the model to explain cross-country productivity differences turned out to be failures.** Under the assumptions of the model, differences in capital labor ratios across countries proved incapable of explaining more than half of the observed differences in output per worker. Further and more generally, there were indications that even if the concept of capital were expanded to include educational attainments, the model would be in serious trouble.

Because of the increasingly evident inadequacies of neoclassical theory, the 1950s were marked by the evolution of a line of research which has broken from the neoclassical structure, and focused on the role of technological change over time and technological differences across countries. Some of this research has concentrated on the role of technological advance as a source of growth. It is now well documented that technological advance, as constrasted with or transcending increase in capital per worker, has been an extremely important source of growth.*** Recent research by Keesing, Vernon, Hufbauer, and others, has been concerned with the effect of technology and technological change on trade patterns.**** Their well-known results

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*I refer of course to the Leontief paradox. See Wassily Leontief "Domestic Production and Foreign Trade; The American Capital Position Re-examined." Proceedings of the American Philosophical Society, September 1953..

**See Kenneth Arrow, et al., 'Capital Labor Substitution and Economic Efficiency." The Review of Economics and Statistics, August 1961.

***See Nelson, et al., op. cit.

****Donald Keesing, "The Impact of Research and Development on U.S. Trade." Journal of Political Economy, February 1967; Raymond Vernon,

are that, to a considerable extent, U.S. manufacturing exports are in new products that other countries have not yet begun to produce in quantity. Vernon and Hufbauer go on to show that, with a lag, other manufacturing nations pick up and employ U.S. technology and gradually cut the United States out of export markets.

By putting these threads together one comes up with a quite different explanation of international differences in productivity than that of the neoclassical model. The main engine of manufacturing development is the creation of new technological knowledge, and its application, above all in the United States, and to a more limited extent in Europe and Japan. With a lag, the other major manufacturing countries pick up the new technology and learn to use it effectively. With a much greater lag, the less-developed countries do. Under this view, one would expect to find differences across countries in the productivity and composition of manufacturing activity that transcend differences in capital and other inputs per worker directly engaged in production.

Whether these differences can be considered "a technological gap," in the sense of not being the direct consequences of the magnitude of investment is, however, a difficult question which cannot be answered in principle. The fact that the United States is the leading country in creating and introducing new products and processes certainly is in part attributable to its past investment in the education of

"International Investment and International Trade in Product Cycles," Quarterly Journal of Economics, June 1966; G. C. Hufbauer, Synthetic Materials and the Theory of International Trade, Ferald Duckworth, 1966. As I will show later, there were many antecedents.

scientists and engineers, in research and development, and in other activities that feed technological progress.

However, the Keesing-Vernon viewpoint certainly has room for a meaningful technological gap to exist. A meaningful technological gap would exist if the causes of technological progressivity in a country transcended resources directly allocated to that purpose, or if these resources yielded an unusually high rate of social return, which actually is quite possible.

A technological gap between countries, in the above sense, should show up in three ways. The first is differences in total factor productivity, which probably will be associated with differences in output per worker but transcends it. Second, one should observe that the leading country is a major exporter in technically progressive industries. Third, the lagging countries should be adopters of technology rather than innovators. The first is necessary, as well as the other two.

It would appear probable that a technological gap, in the above sense, does exist between the United States and Europe, at least in many industries. The trade and adoption aspects of the phenomenon are of course well documented. It is far harder to document the total factor productivity differential. Denison, in his recent study, concluded that, under his assumptions, differences in productivity between the U.S. and Europe cannot be fully explained by differences in capital-labor ratios, educational attainments or other differences in relative quantities and qualities of factors of production.[*] The total

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[*] Edward Denison (assisted by Jean-Pierre Poullier), Why Economic Growth Rates Differ, The Brookings Institution, 1967.

factor productivity difference he estimates cannot be explained simply by resources invested in R&D unless an extremely high rate of return is assigned to the latter. One cannot prove the existence of a gap, but it appears quite likely.

II. THE TECHNOLOGICAL GAP AS A LONG-STANDING PHENOMENON

The recent discussion of the technological gap not only asserts that it exists, but that it is something new. Some of the more careful students of the phenomenon have pointed out that it isn't all that new, citing the various comparative productivity studies made just after World War II that showed that a "gap" existed then. But I want to suggest that the phenomenon is of far longer standing than that.

In 1835, the namesake of this series commented in several places on developing American economic prowess in various fields. Thus regarding shipping:

> It is difficult to say for what reason the Americans can navigate at a lower rate than other nations; one is at first led to attribute this superiority to the physical advantages that nature gives them; but it is not so.... I am of the opinion that the true cause of their superiority must not be sought for in physical advantages, but that it is wholly attributable to moral and intellectual qualities.*

And not just in shipping.

> The United States of America has only been emancipated for half a century from the state of colonial dependence in

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*Alexis de Tocqueville, Democracy in America, Vintage Books, New York, 1955, Vol. I, p. 441.

> which it stood to Great Britain; the number of large fortunes there is small and capital is still scarce. Yet no people in the world have made such rapid progress in trade and manufactures as the Americans....*

Habakkuk opens his excellent recent work on American and British Technology in the Nineteenth Century by confirming and reinforcing de Tocqueville's judgment.

> There is a substantial body of comment, by English visitors to America in the first half of the nineteenth century, which suggests that, in a number of industries, American equipment was, in some sense, superior to the English even at this period. As early as 1835 Cobden had noted, in the machine shop of a woollen mill at Lowell, "a number of machines and contrivances for abridging labour greater than at Sharp and Robers." He thought agricultural implements in New England exhibited "remarkable evidences of ingenuity...for aiding and abridging human as well as brute labour," and gave several other instances. And the two groups of English technicians who visited America in the 1850s reported that the Americans produced by more highly mechanised and more standardised methods a wide range of products including doors, furniture and other woodwork; boots and shoes; ploughs and mowing-machines, wood screws, files and nails; biscuits, locks, clocks, small arms, nuts and bolts.**

The evidence of a technological gap in many fields prior to 1850 essentially is the record of scattered non-quantitative impressions of sophisticated and knowledgeable visitors. After 1850 we have access to more quantitative evidence. All three facets were present; higher total factor productivity, a strong export position in technically progressive industries, and foreign (European) adoption of the U.S. practices.

It is very clear that by the 1860s and 1870s real per capita income was significantly higher in the United States than in the

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*Ibid., 1954, Vol. II. pp. 165-166.

**H. J. Habakkuk, American and British Technology in the Nineteenth Century, Cambridge University Press, 1962, pp. 4-5.

United Kingdom or Western Europe. Kuznet's data show that, if anything, the percentage difference between the United States and France and Germany was greater in the mid-nineteenth century than today, and the relative gap between the United States and England was only slightly smaller than than now.* In part this was due to the high productivity of American agriculture. But value added per worker almost certainly was higher in American manufacturing industry.

It was higher for at least two reasons. Even by that time a large number of industries in the United States probably were operating at a higher capital-labor ratio than their English or European counterparts. This is both explained by and explains the significantly higher wage rate in U.S. industry. High American wages go back at least as far as 1830, and scattered evidence suggests that by the 1870s U.S. wages may have averaged perhaps twice that in the United Kingdom (and even more, relative to France and Germany). But this cannot be the full explanation. If it were simply greater capital intensity, but the same total factor productivity, the rate of return on capital should have been significantly lower in the United States. The limited evidence suggests, rather, that it was higher. Over the second half of the nineteenth century the yield on British consols never got above 3.5 percent; the yield on the best American railway bonds (to be sure, somewhat more risky) never sunk that low and tended to be over 5.0 percent.** Relatedly, this was a period when capital

*Simon Kuznets, Modern Economic Growth, Yale University Press, 1966, pp. 64, 65.

**William Fellner, Trends and Cycles in Economic Activity, Henry Holt and Company, 1956, pp. 396, 397.

was flowing from the United Kingdom to the United States, not the other way around.

Between 1880 and 1910 the growth of U.S. finished manufactured exports increased more than six fold; imports less than tripled. The United States, which ought to have and clearly did have a great comparative advantage and large net export position in foodstuffs (which made exchange available for manufactured imports) nonetheless was a net exporter of manufactured products by 1900. A good share of the surge was in "technically progressive" industries. By 1899 about one-third of U.S.-manufactured exports were in machinery, chemicals, or vehicles.* For Germany and the United Kingdom the figure was about one-fifth. The value of U.S. machinery exports increased ten-fold between the mid-1880s and 1905-1906. It would appear that around the turn of the century the United States dominated trade in typewriters, for example.**

This evidence suggests a significant "technological lead," not surprisingly, for the last half of the nineteenth century was indeed the well-known great age of American invention. It was also the era in which the system of interchangeable parts was rapidly coming into play in industry after industry in the United States. In many fields Europeans and Englishmen were busy picking up American technique with a lag, just as today. Of course it was not a one way street. The

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*All data cited for U.S. exports during the late nineteenth and early twentieth centuries are from The Historical Statistics of the United States, U.S. Department of Commerce 1960.

**See the paper by Richard N. Cooper, In Technology and World Trade, U.S. Department of Commerce, 1967.

Americans did not lead in all fields, and in many fields the lead changed hands. Sometime during the nineteenth century the U.S. lost its lead in shipping. The English and Europeans developed, and then lost to the Americans, the lead in steel technology. But that on the average, in some sense, the Americans were the technological leaders in manufacturing industry seems clear.

There is evidence of considerable concern, at least on the part of some Europeans. Viner presents the following quote from a 1897 letter circulated by Count Goluchowski, the Austrian Foreign Minister:*

> Europe has apparently reached a turning-point in her development. The solving of the great problem of the material well-being of nations, which becomes more pressing from year to year, is no longer a distant Utopia. It is near at hand. The disastrous competition which, in all domains of human activity, we have to submit to from over the seas, and which we will also have to encounter in the future, must be resisted if the vital interests of Europe are not to suffer, and if Europe is not to fall into gradual decay. Shoulder to shoulder we must ward off the danger that is at our doors, and in order to prepare for this we must draw upon all the reserves that stand at our disposal.
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> ...the twentieth century will be a century of struggle for existence in the domain of economics. The nations of Europe must unite in order to defend their very means of existence. May that be understood by all, and may we make use of those days of peaceful development to which we look forward with confidence, to unite out best energies.

Interestingly, while today the laments of the Europeans have pretty much monopolized the stage, the Americans were then bothered by the phenomenon too, not the lead but the European and English rapid adoption of U.S. technology. It was recognized by at least some observers in the United States that the reason why U.S. industry was able to pay such high wages, still earn such a high rate of

*From Jacob Viner, The Customs Union Issue, Anderson Kramar Associates, 1961, pp. 22-24.

return, and yet remain competitive in world markets, lay in its technological lead. In 1915 Taussig commented as follows on the rapid diffusion of American technology in automatic machinery:

> The more machinery becomes automatic, the more readily can it be transplanted. Is there not a likelihood that apparatus which is almost self-acting will be carried off to countries of low wages, and there used for producing articles at lower price than is possible in the country of high wages where the apparatus has originated? In hearings before our congressional committees a fear is often expressed that American inventors and tool-makers will find themselves in such a plight. An American firm, it is said, will devise a new machine, and an export of the machine itself or of its products will set in. Then some German will buy a specimen and reproduce the machine, in his own country (the Germans have been usually complained of as the arch plagiarists, very recently, the Japanese also are held up in terrorem). Soon not only will the exports cease, but the machine itself will be operated in Germany by low-paid labor, and the articles made by its aid will be sent back to the United States. Shoe machinery and knitting machinery have been cited in illustration.*

Thus it is clear that a technological gap, with most of its associated economic phenomenon, has existed for a very long time, and so has concern about it. Concern was, of course, greatly sharpened in the early post World War II years when, as a result of the war, disparities between U.S. and European economic capabilities were particularly great. With the beginnings of rapid recovery in Europe in the early 1950s, the technology gap phenomenon again faded from the headlines. When it returned it was brought back by the Americans. Almost echoing the Taussig laments of a half-century earlier, in the very early 1960s there was considerable ferment within the U.S. scientific community, and in Government, that the United States was

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*F. W. Taussig, Selected Readings in International Trade and Tariff Problems, Ginn & Co., Boston, 1921, p. 138; reprinted from Chapter 3 of Some Aspects of the Tariff Question, 1915.

losing its technological lead to the Europeans. The erosion of technological lead was widely believed to be a major factor explaining the worsening U.S. trade position in the late 1950s and early 1960s. Thus in the report of the Commission on Money Credit:

> The apparent reduction in the time lag between the adoption of new techniques and new processes in the United States and their imitation abroad has also strengthened the competitive position of foreigners. For many years the United States has been a technological innovator and an exporter of technology. Prices of U.S. manufactured products remained competitive despite higher U.S. wages because of advanced technology and large-scale production. The more rapid adoption of advanced technology abroad weakens our competitive position in relation to countries with lower-paid labor.*

It is somewhat puzzling that once the spate of gap speeches began in Europe, the European case so rapidly preempted the stage. In the bibliography collected by the organizers of this conference there is not a reference to the American internal debate -- which posed the problem exactly the other way -- of just a few years ago.

It is less puzzling why so much attention has suddenly been paid to a hoary problem. Let me try to suggest what is really new, and why the new concern and awareness exists.

III. WHAT IS NEW, AND WHAT IS THE SIGNIFICANCE?

Certainly the flurry of awareness was not triggered by any objectively poor economic performance of the European countries. Until just recently it was the lagging U.S. growth rate that was the obvious phenomenon, not slow growth in Europe. (The British clearly

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*Report of the Commission on Money and Credit, Money and Credit, Prentice Hall, 1961, p. 222.

are a special case.) Nor is there any evidence of deteriorating competitive prowess of Europe vis-à-vis the United States regarding manufacturing exports. United States (plus Canadian) exports and imports of manufactured goods to Europe and the United Kingdom were roughly in balance in 1950. Between 1950 and 1960 U.S. exports to Europe increased barely 50 percent, while European manufacturing exports to the United States roughly tripled. By the early 1960s the Europeans had far larger relative positive balance of manufacturing trade with the United States than they had had since at least 1890 or so.* Partly because of this, it was the United States that recently has had the balance of payments problem, not the Europeans (again England is a special case).**

It, of course, has been argued that it is not the overall balance of manufacturing trade that is the issue, but the nature of the trade, with the United States having the advantage in the new and complex products area. But I have argued above that this has been so for a long time. Further, since 1953 the U.S. share of exports in the industries generally labeled as technologically progressive has fallen significantly. Thus between 1953 and 1961 the U.S. share of the exports of electrical machinery have fallen from 36 to 26 percent, of nonelectrical machinery from 44 to 34 per cent, transport equipment 37 to 25 percent, chemicals from 34 to 32 percent. The big

*Alfred Maizels, Industrial Trade and World Growth, Cambridge University Press, 1963, p. 100.

**I do not mean to ascribe a balance of payments problem to a particular item, of course.

gainers have been the European nations and Japan.*

What is new is a far sharper awareness of the situation, and, among at least some Europeans, a relatively new deep-seated concern about its significance. There would appear to be four basic reasons, related but separable.

One is the vast increase in the volume of trade in manufactured goods which has made foreign products vastly more visible on both sides of the Atlantic. In 1950 trade in manufactures between North America and Europe was only at about 1929 levels.** Between 1950 and 1965, as noted earlier, U.S. exports to Europe rose sharply and exports from Europe to the United States rose even more. Europeans and Englishmen were increasingly aware of the U.S. products pouring into their homes, factories, and stores. On the American side of the Atlantic, Volkswagens and Jaguars became familiar sights, we flew in Viscounts and Caravelles, we drank European beer and wine as well as Scotch and Scandinavian furniture became the rage. The interesting question is why the difference in attitudes on the two sides of the Atlantic to the invasion of foreign goods.

Certainly part of the explanation lies in the second major new phenomenon of the 1950s. Related to the sharp increase in trade between the major manufacturing nations, there was an explosion in international direct investment. As with trade, it has been a two-way street. But unlike trade, where U.S. imports from Europe increased much more rapidly than European imports from the United States, here

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*Bela Balassa, "Recent Developments in the Competitiveness of American Industry and Prospects for the Future," Joint Economics Committee, Factors Affecting the U.S. Balance of Payments, 87th Congress, U.S. Government Printing Office, 1962, p. 45.

**In 1955 prices. See Maizels.

the relationship has been the other way around. In the mid-1930s total European direct investments in the United States and U.S. direct investments in Europe appear to have been roughly of the same magnitude, and this also was the situation as of 1950.* But since 1950 European direct investments in the United States have tripled in value; U.S. direct investments in Europe have increased eightfold. The reasons for the internationalization of American companies still are far from perfectly understood. Undoubtedly a powerful reason is the decreased cost of international communication and travel, which also lies behind the international trade explosion. Nor are the benefits and costs to the home and host country well understood. But it is clear that some Europeans are seriously disturbed about the size and economic power of the American firms, and have the impression that American firms are beginning to own Europe.

A third major development of the postwar era has been the striking move to leadership in basic science of the United States. While U.S. technological leadership appears to be a long standing phenomenon, American leadership in basic science certainly is not. As late as 1930 American scientists ranked far below Germany and the United Kingdom, and below France in terms of Nobel prizes, earning less than 10 percent of the total awarded in the twenties. In the 1950s nearly half of the Nobel prizes went to Americans -- the American percentage, and the lead over its closest rival (the United Kingdom) being even greater than German percentage in the 1911-1920 period and

*See Foreign Business Investments in the United States, U.S. Department of Commerce, 1962, p. 1462, and U.S. Investment in Foreign Countries, U.S. Department of Commerce, 1960, p. 93.

her lead over her closest rival (the United Kingdom).* Comparative data for expenditures on, or manpower engaged in, research do not extend back very far. However, it is highly likely they show a similar trend -- the United States spending relatively little on research in the early twentieth century, and becoming dominant in the postwar era.

On the latter point the data are clear. The rapid growth of basic research spending in the United States has been part and parcel of an explosion of spending on organized R&D generally. Subject to all kinds of qualifications regarding who is included as a scientist or engineer, and what is counted as research and development, in 1962 the United States spent roughly four times more on R&D than did Europe (including the United Kingdom).** We had three times more scientists and engineers engaged in R&D, and roughly three times the percent of the work force. With respect to basic research, the difference is somewhat smaller, but still large. The R&D gap, as the technology gap, certainly is real; it has been rather easily assumed (implicitly) that they are the same thing. The fact that one is new and one is old indicates clearly that they are not.

Associated with the rise of U.S. R&D spending has been an accelerated flow of European scientists and engineers to the United States. This flow, as the technological gap, has been a long standing

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*Arthur D. Little, Inc., Basic Research in the Navy, Distributed by the U.S. Department of Commerce, 1960, p. 30.

**A useful reference is C. Freeman and A. Young, "The Research and Development Effort in Western Europe, North America, and the Soviet Union," OECD, 1965.

phenomenon. The science departments of some of the best American universities long have had significant European representation. But certainly in terms of absolute quantities, the flow has been much greater in the postwar era. Many, but far from all, of the European scientists and engineers are being employed by the American corporate giants. When in juxtoposition with the phenomenon of the growing U.S. corporate presence in Europe, the flow of many of Europe's best technical people to the U.S. appeared particularly ominous. To some people it appeared that, not only were U.S. corporations beginning to own Europe, the U.S. was stripping from Europe the key to her ability to compete with American companies.

It is important to note however, that the R&D gap is largely concentrated in three fields -- aircraft and missiles, atomic energy, and electronics. This is extremely significant. For in some respects the most important new development of the postwar era has been a dramatic change in the basis of military strength. This is not the time or the place to discuss again this oft-discussed topic. Suffice it to say that with respect to at least nuclear war, for a country that aims for an independent defense capabilities, the risks of not staying up with or ahead of a possible antagonist in terms of technology have never been so great, nor have the R&D outlays needed to maintain parity with respect to military technology. There is, indeed, a military R&D race between the major powers. Achieving military parity is not a one-shot proposition but requires a massive and continuing R&D effort. The recent American decision to follow the Russians in building at least a nominal active defense system to neutralize the capability of small and relatively unsophisticated

strike system demonstrates this viv...iy. European awareness of this fact has been slow in coming. As it has come, it has been combined with growing discontent with certain of the foreign policies of the United States and hence grave unrest about second-class power status on the part of at least some Europeans.

It is easy to understand why these four developments -- a surge of world trade, a significant increase in U.S. foreign direct investment, the growing power of U.S. in basic science and the associated brain drain, and the military dominance of the U.S. in the western alliance -- can be viewed by some as a single phenomenon and lumped together under an umbrella explanation -- a technological gap. It has been the lumping together of the phenomennon (together with a misinterpretation of the post war trade and growth experience) that has led some people to view certain consequences as inseparable -- loss of foreign policy autonomy in certain key respects, reduced national control over the domestic economic system, and a threat to national economic well being and growth.

Yet clearly the phenomenon, although related, are separable, and the alleged consequences are separable. Some are significant, others are overstated, some are easy to deal with, others difficult or impossible.

It seems to me extremely important to distinguish between the consequences of the technological gap in terms of military power (where it obviously is extremely important) and the consequences in terms of economic welfare and growth. As pointed out earlier the technology gap has never been a phenomenon that held across all

industries, nor is it now. In ship building, various facets of steel making, various optical devices, and in high precision machine tools, it is clear that the Americans are, in certain respects at least, lagging behind the Europeans and the Japanese. Further, the fields where the Americans have had a significant lead have switched over time. The American lead in shipping and ship building was lost long ago. The lead in steel technology has switched from Europe to the U.S. and now apparently back again. The American lead in military related technology is the striking new phenomenon, and its political implications are of course profound. But except insofar as European nations invest or plan to invest R&D resources to establish a more independent military position, it is not at all clear that the economic implications are particularly adverse.

Similarly, the issue of American ownership and management of European business and the issue of alleged economic problems for the Europeans that are intrinsic in the gap seem separable. While this appears an efficient way to achieve international flow of technological knowledge, it certainly isn't necessary. The Japanese, for example, have rapidly and effectively adopted U.S. technology but have had a conscious policy of excluding U.S. owned companies.

As a general economoc phenomenon, there is nothing in recent history to suggest that the "gap" is causing the Europeans much economic trouble. The fact that the United States is the innovator means that the United States will tend to be ahead of the Europeans with respect to both productivity and product in the technologically progressive fields. And this means that the standard of living in

the United States will be higher and the United States will be the major exporter of these good. But in part, at least, this is because we are doing the heavy investing in the activities which create new technology. Other countries are getting, more or less for free (licenses probably in most cases are a bargain), the benefits of our investing, if with a lag. To a considerable extent the power of the European economy to produce goods and services is as high as it is because of the technological progressivity of the United States. While it may be somewhat galling to be a follower, if a follower one is, it might be argued that it is desirable to have a progressive leader. But many Europeans do not view it this way, and in Section V I shall try to present a few of their arguments.

IV. WHAT LIES BEHIND THE GAP

If in fact the military and general economic consequences of the gap are separable, if the gap does not carry of necessity growing control of European industry by large American corporations, and if the economic effect per se of the leadership position of the United States is generally benign, then, while the several policy issues interact, they should be distinguished. One important policy issue is the division of labor and responsibility within the NATO alliance. A second is the issue of international direct investment and the control and limitations that should be put on it. A third is policy that the Europeans can adapt to increase their own growth rate. I wish to talk here about the last with particular focus on what the U.S. experience might suggest, although I do not think this is the central issue.

In some of the recent discussions of the gap the three issues

have been lumped together not only because of their joint occurrence, but also because of belief that the causes of the gap in economic technology are intimately connected with the other facets of the perceived program. The assumption has been that the principal factors behind the widespread economic technological gap have been the massive defense and space R&D spending of the U.S. government, and the size of U.S. manufacturing corporations.* This point of view naturally leads to a policy of solving all three problems at once by mounting a defense and space R&D program, and by actively encouraging the development of European corporate giants to match the Americans. Thus these two explanations of the gap are worthwhile examining.

Obviously the U.S. lead in military technology is in good part the result of massive defense R&D spending by the U.S. government. Obviously also the knowledge, experience, and organization built up under defense and space R&D contracts has contributed to the U.S. capability to design and build commercial aircraft, has in some respects facilitated the evolution of non military computer technology, has had a diffuse if possibly important effect on the ability of U.S. companies to employ certain widely useful process techniques, and has influenced a few other fields. However, it is important to note that the American technological lead long predated this government defense and space R&D spending. Even more important, it is highly doubtful that the spillover from defense and space R&D is a particularly important factor explaining the American technological lead in recent years except in a quite narrow range of fields.

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*In particular, see P. Cognard, Recherche Scientifique et Independence, Bruxelles, October 27, 1964, and other writings by Cognard.

This does not appear to be the place to review the various studies of spillover. Suffice it to say that the list of clean cut direct spillover examples is not impressive, only a very small percentage of patents resulting from defense and space R&D have ever been used commercially, and scattered interviews with executives of companies engaged in both defense and civilian market activities do not in general indicate a striking benefit to the latter from the former. Even in the fields of aircraft and computers, where the spillover is assumed to be large and direct, there is reason to believe that the direct transferabilities of the results of military R&D to civilian design is not as direct as might be believed.*

If spillover is limited then far from being close complements, actions to close the military technology gap and the civilian technology gap may be substitutes. With given scientific and technical resources one must trade one off against the other. In the United States there certainly is a point of view that large defense and space R&D programs are hindering the ability of the United States to keep a general technological lead, not helping it. As pointed out earlier, just before the recent expression of European concern about the gap, the United States had begun to be concerned about it, or rather its pending loss. Some people viewed the villain in the piece as the large U.S. defense and space R&D program which preempted scientific and technical resources from civilian R&D. It was warned that in industry after industry the Europeans and Japanese, not burdened by such a massive unproductive use of R&D resources, were overtaking us.

*For a review of the literature see Nelson, Peck, and Kalachek, ibid.

The following quote is from J. Herbert Hollomon, then Assistant Secretary of Commerce for Science and Technology:

> Presently, there are about 350,000 people in industry who perform research and development. But of these, only about 120,000 are supported by industry for civilian industrial purposes. The remainder are supported by federal programs that have to do primarily with military preparedness, weapons systems, atomic energy, and the rapidly increasing space effort. This increased government support for research and development performed by industry has not only changed the character of industrial research and development, but also has changed the factors which influence its cost. Special contractual arrangements usually require physical and organizational separation of government-supported "research and development" from the privately supported. This separation makes it difficult for one to benefit the other and for techniques and discoveries in one area to spill over to the other.*

The Council of Economic Advisers also was concerned about the unbalance of U.S. R&D:

> In recent years, there has been a dramatic increase in total expenditures on research and development and in the number of scientists and engineers engaged in these activities. However, defense and space efforts have accounted for nearly three-fourths of the increase. The research laboratories of industry and the universities have been important sources of new products and processes for the civilian economy, but most private research and development is still concentrated in a relatively few industries and is carried on by a few large firms. With the exception of a few hundred manufacturing firms most enterprises neither undertake much research and development nor have sufficient trained technical manpower to take advantage of the research and development done by others. Our economy would be strengthened significantly over the long run if our civilian research and development resources were expanded to meet better the wide range of private and public needs.**

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*J. Herbert Hollomon, "Science and Innovation," from Economics of Research and Development, edited by Richard A. Tybout, Ohio State University Press, 1965, pp. 251-253.

**Economic Report of the President together with The Annual Report of the Council of Economic Advisers, transmitted to the Congress January 1963, U.S. Government Printing Office, Washington, 1963, p. 63.

The role of the American corporate giants in the creation and application of new civilian technology is another phenomenon that often seems to be both exaggerated and misspecified. There is no denying the extremely important role played by the giant firms in many fields. There are many reasons why, in certain situations at least, giant corporations have a strong advantage in doing what is needed to advance technology, and why, in some circumstances, small or even medium sized firms simply cannot do the job. One important reason is that, sometimes, the size of the required R&D effort, its cost, and the cost of the investment and other activities needed to bring into operation the new technology or product, simply transcend the resources of any but giant firms. This has been predominantly the case in many areas of postwar military technology. It takes an extremely large firm to develop the principal components of modern missile and aircraft systems. European experience with these systems, as well as certain other perceived advantages of the American corporate giants, certainly has conditioned a belief in the advantages of size.

But it is easy to generalize falsely from missile systems to civilian technology, and from some areas of civilian technology (large commercial aircraft) to civilian technology in general. It simply is not so that in all, or most, fields, the costs of inventing, developing, and introducing technology are all that great. Reflecting this, in almost all product fields small companies have played an extremely important role in investing, developing, and introducing new technology. The study by Jewkes, Sawers and Stillerman documents this convincingly

up to about 1950.* There is no comparable comprehensive study that examines the post 1950 period, but certainly in electronics the small and medium size companies have continued to be important sources of new technology.

However, the right way to pose the issue is not the contribution of the corporate giants versus smaller firms and individual inventors To a considerable extent firms of different sizes do different things. In most industries there is a wide menu of important R&D work to be done, some projects involving much higher costs than others. Obviously it takes a large company to undertake really expensive R&D projects (like developing a supersonic aircraft). But evidence seems to suggest that where R&D costs are not particularly high (generally for smaller scale systems) the small and medium size firm subsector of an industry is at least as likely to be technologically progressive as the giants of the industry. Further, costs and uncertainties differ at different stages of the R&D process. Very often the relatively low cost but high risk early exploratory work is initiated by a small company, with the subsequent high cost, lower risk development taken over by a larger company. The Whittle jet engine is an excellent case in point. And many of Duponts most important product innovations represented development of work initially done outside of Dupont by smaller companies.

In the United States, as contrasted with Europe, there has been growing concern that industries dominated by the giants may become

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*John Jewkes, Davis Sawers, and Richard Stillerman, The Sources of Invention, Macmillan, 1958.

technologically stagnant. During 1965 a series of hearings before the U.S. Senate subcommittee on Anti-trust and Monopoly was focused on just this.* In particular, the loss of American leadership in steel technology has been ascribed to the comfortable oligopoly structure that the large companies have developed for themselves. If this point of view is correct, policies to match the U.S. corporations in size may not always help, but sometimes may hinder, the technological progressivity of European industries.

Looking at the matter more positively, what is there in the U.S. experience that may provide useful guidance? Knowledge of the factors that explain major economic differences across countries still is very limited. However, I would like to suggest that the following three, quite well known and quite prosaic, factors have been pivotal in explaining the technological progressivity of the U.S.

First, a belief in economic progress, in competition as a vehicle of progress, and in the mobility of resources. While sometimes this has amounted to lip service and from time to time policy has been dominated by particular business interests, by and large there has been little concern about protecting particular business entities from competition, or of protecting the work force from frictional or structural unemployment. There has been considerable concern that new ideas and new firms have a chance to enter and compete.

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*Economic Concentration, Hearings Before the Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary, United States Senate, Part 3, Concentration, Invention, and Innovation, May 18, 24, 25, 27, and June 17, 1965.

This did not mean that the American government did not help business. It certainly did, but generally through investment to help business in general. The attitude toward individual businesses tended to be much in the spirit of survival of the fittest.

Second, a powerful belief, and the provision of funds to back it up, in the practical value of universal education up to increasingly high levels, and the conscious building and molding of educational institutions to be responsive to practical needs. Over the years this has meant differing things. In the early nineteenth century a drive for universal primary education. In the mid-nineteenth century the land grant colleges. In the mid-twentieth century universal high school education, M.I.T., the business schools, and the University of California system. The result has been the creation and maintenance of both a large proportion of the population capable of understanding technologies well enough to innovate, and of a general work force capable of learning to use new technology rapidly and easily.

Third, the size of the American market has always been large relative to that of an efficient sized firm. When the internal market was small during the early nineteenth century, the economies of scale in most industries were very limited. As technology evolved so as to increase scale economies, the size of the market grew. Thus with limited exceptions, the United States has not had to face the problem that competition itself could produce monopoly. The large scale of the American market, together with considerable freedom for competition, meant that the rewards for successful innovation could be very handsome.

My list of key factors is quite traditional; I claim no originality. Nor are they offered in a spirit of piety, or with the notion that they are either a sure fire or the only set of effective conditions for rapid economic progress. I suspect that large scale markets probably are a necessary condition, increasingly so now that large scale economies exist in almost all economies. Mass high level education I suspect also is probably necessary, at least if technological competence across the board rather than in a few selected industries is the target. It is significant that most European discussion of needed economic policy changes has for some time recognized these two necessary conditions, and since World War II they have been actively sought. Let me delay for a moment my discussion of the first factor -- encouragement of competition, belief in mobile factors, and unwillingless to treat particular business entities as "chosen instruments."

For a major thrust of much of the recent literature on public policy to stimulate technological advance implies a very different approach.* To a considerable extent at least much of modern thinking carries the thrust of substituting a considerable measure of direct government R&D spending or directed support of private R&D, complementing an evolved form of economic planning, for private competition. While the exact nature of the proposed policies are often ambiguous, in some sense the proposal seems to amount to developing an economy-wide system with many elements in common to the system that has been adopted in the United States regarding defense and space.

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*See, for example, the OECD publications, Science and the Policies of Governments, September 1963, and Government and Technical Innovation, 1966.

Regarding how to run such a system, the experience of the United States sheds only a little light. On one of the pivotal elements -- public support of industrial R&D, with some considerable measure of planning, the U.S. has had almost no relevant experience at all. The reason is simple. The U.S. really has not had any such policies. With respect to applied industrial R&D, except where the government has had a direct interest in the final product field, traditionally the job was left to the incentive provided by the patent system and the initiative of private enterprise.* Indeed, the support of basic research, with an eye to industrial growth, has only been a post World War II phenomenon.

It is clear that an active policy toward science and technology is much more important now than years ago. Technological advance in most industries today is much more closely linked to formal R&D than was the case years ago. In turn, both the supply of formally trained scientists and engineers, and the basic science efforts of the country are vastly more important. Both of these must be of central concern to government. And both the magnitude and allocation of government support of technical and scientific education and of basic research will profoundly effect the rate and direction of technological change. If the government could afford in the past not to have an active policy toward science and technology, this is no longer the case today.

However, it is not at all clear just what the dimensions and

*Agriculture is an important exception, but we are talking about manufacturing technology. For a history of U.S. policy, see Nelson, Peck, and Kalachek.

characteristics of an active science and technology policy should be. It most certainly should involve more than the strict neutrality with respect to the magnitude and allocation of industrial R&D that has marked the U.S. experience until just recently. I suspect it should involve considerably less than the degree of government planning and support that the U.S. now has in defense and space. This has proved a good system for achieving rapid technological advance in a relatively narrow and well defined area, but it has been extremely costly. It seems an inconceivable approach to a general policy.

The notion of government sponsoring of civilian R&D, and the role of competition versus a chosen instrument, are, of course, closely related. If the government directly supports particular industrial R&D projects in particular companies or groups of companies -- as it has in the United States in defense -- the role of competition is greatly diluted. Implicitly if not explicitly the favored companies are chosen instruments. Their success or failure cannot be a matter of indifference to government.

The philosophy of fostering open competition with little concern for who got burnt in the process worked well in the United States, but in some cases the social costs were high. It is certain that modern active labor market policy can greatly reduce these costs. And it is quite possible that the evolution of modern sophisticated planning and control techniques has permitted an effective partial substitute for the market carrot and stick. And a policy of at least partially abandoning the carrot and stick is a necessary concomitant of a governmental program of planning and allocating R&D resources in a field.

But if the government cannot allocate the nation's R&D resources in detail, and has trouble predicting the results that come even where it does control the R&D inputs in a field, it would appear that competition -- which means some companies lose and some gain much more than is expected -- is still an important facilitating factor for an economy that aims to be technologically progressive. And there may be a sharp conflict between detailed sector planning and technological progressivity. When the objective of policy makers is to more effectively employ technology that is known and available and used elsewhere, a symbiotic relationship between a set of business firms and the government can be a powerful engine of progress. Where the government's objectives are to move the technological frontiers in a particular well defined field and costs are of little concern, such a relationship also can work well. It may be far less effective, and something like competition far more important, in fostering technological progress across the board.

VI. THE APPARENT EUROPEAN INTEREST IN ADVANCED TECHNOLOGY PER SE*

It is highly unlikely that arguments of the sort developed in the preceding section, even if vastly better documented, would be able to persuade the Europeans. Nor would it help to argue that a massive R&D program is not likely to be an efficient way to deal with such important problems as improving housing, urban transportation, etc. Even if these arguments were accepted, they would not disuade many Europeans from going ahead with a "big science and technology" policy

*This section was written after the Conference in Turin as a postcript to the orginal manuscript that seemed called for by the discussions.

with all the trimmings -- large government R&D contracts to large corporations justified in considerable part by the argument that some other country is engaged in such a program and is (or may get) ahead. We are likely to see many more episodes like the supersonic transport (for which, it appears to me, no one has presented a case not based largely on that someone else was doing it, or planning to).

The argument that it is dangerous to let another country gain a large technological lead in an important and dynamic field obviously is relevant for a country (or group of countries) that is concerned about military power. Clearly this is part of the story, but I am well aware there is more to it than this. Apparently not being behind technologically in the most revolutionary fields has been, or is becoming, an aspect of national sovereignty. Here the direct foreign investment issue enters in an exacerbating way. The question of economic well being enters the picture, but in an unconventional way. In part a "big science" policy can be justified, or rationalized, in terms of the value of options. Thus even many Europeans who do not believe, or will not profess, that a European strategic capability is needed now, will argue that the option to build one is important in alliance negotiation, and to guard against a change in the world environment. Many Europeans who would agree that in principle, if "reasonable" terms could be assured, it would be far cheaper to buy aircraft, or computers, from the United States than to invest vast sums in R&D, will argue that having the technological capability to produce aircraft and computers gives important bargaining leverage to assure reasonable terms, and guards against future adverse developments.

Thus while there is a strong economic rationale in these kinds of arguments, it is not a conventional one. And it cannot be met by conventional counterarguments. Americans may be justified in claiming that the Europeans from time to time sound as if they are arguing conventional economics, and Americans might well argue that Europeans are being unfair in assigning such a high value to independence options, and underestimate the price. However, it would be well to get the issues straight (or at least a bit straighter) on both sides of the Atlantic. Otherwise we shall continue to talk past each other.